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Abstract

# CALCULATION OF CRITICALITY, POWER DISTRIBUTION AND FUEL BURNUP IN THERMAL POWER REACTORS

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Analytical methods currently in use for the calculation of criticality, power distribution and fuel burnup in thermal power reactors are reviewed. Emphasis is placed on specific phenomena to be accounted for in the calculations and on procedures for integrating the basic elements of the calculation into an overall analysis. Aspects of the analysis are discussed in terms of their significance for specific reactor types.

Elements of the criticality calculation are examined with emphasis on the analytical methods being utilized in the treatment of neutrons slowing down and for the determination of reaction rates as a function of energy in the reactor core. The status of the nuclear data for important fuel and structural materials is discussed in terms of the correlation of calculations with critical experiments and of the effects of uncertainties on specific aspects of design calculations. Alternative procedures for the homogenization of the fuel-rod moderator lattice unit cell are described and compared. In the energy range of the fission source, fast fission and inelastic scattering, analytical methods involving lattice escape probabilities are compared with those based on Monte Carlo calculations. In the epithermal energy range, methods of analysis based on the use of resonance parameters in Monte Carlo calculations or in calculations as developed by Chernick and Nordheim are compared with methods based on the utilization of experimental resonance-integral data. In the thermal-energy range, alternative procedures for the determination of the unit-cell disadvantage factor are described, and the results of calculations utilizing various approximations are inter-compared.

Significant factors in the determination of the overall reactor power distribution are described. Complications arising as a result of the geometrical complexity associated with non-uniform fuel loading and partial re-fueling schemes are pointed out. Methods for the determination of group constants for few-group diffusion theory are described, and comparisons between calculated and measured power shapes in complex reactor configurations are presented. Effects of nuclear/thermal/hydraulic interactions on the power distributions in water-moderated reactors are considered, and methods for accounting for such effects are described. Problems arising from the sensitivity of the power shape to local reactivity in low-buckling cores are discussed. Limitations of earlier methods for the determination of three-dimensional power shapes are discussed, and the advantages associated with modern synthesis procedures for the construction of three dimensional power shapes are described. Data are presented comparing the results of conventional numerical calculations of neutron-flux distribution with those obtained utilizing flux-synthesis techniques. Relative computing times are also discussed.

Calculational methods utilized in reactor nuclear design for the determination of reactivity lifetime and for the specification of fuel-cycling procedures are reviewed. The influence of the reactor moderator properties and of the variation with lifetime of the characteristics associated with reactivity control on the analysis of reactor fuel depletion is considered. Special characteristics of the thorium/uranium fuel cycle and of the uranium/plutonium fuel cycle are indicated. Experimental data available for the evaluation of reactor fuel burnup calculations are reviewed, and comparisons between the results of fuel-burnup calculations and spent-fuel isotopic analysis are presented. Important processes involved in reactor fuel depletion are discussed, and the limitations associated with the methods of analysis currently employed are outlined. The potential of new methods of analysis, based on the calculus of variations, for the study of reactor power distribution as a function of time is discussed.